CLAIMS

1. A gas-mixture-ignition-time estimation apparatus for an internal combustion engine which comprises premixed-gas-mixture-autoignition-start-time estimation means for estimating a time at which a premixed gas mixture previously formed through mixing of a cylinder interior gas and fuel starts autoignition upon compression, the cylinder interior gas being a gas within a combustion chamber, and the fuel being fuel for premixed-charge compression ignition combustion injected into the combustion chamber earlier than a near compression top dead center and being different from fuel for diffusion combustion injected into the combustion chamber at the near compression top dead center, the gas-mixture-ignition-time estimation apparatus being characterized by comprising:

compression-start-time cylinder-interior-gas-state-quantity acquisition means for acquiring a state quantity of the cylinder interior gas at the time of start of compression of the cylinder interior gas;

compression-attributable-cylinder-interior-gas-state-quantity-change-amount estimation means for estimating the amount of a change in the state quantity of the cylinder interior gas attributable to compression of the cylinder interior gas; and

cool-flame-heat-generation-quantity estimation means for estimating a cool-flame-heat-generation-quantity-corresponding value, which is a value corresponding to a heat generation quantity of a cool flame generated prior to autoignition of the premised gas mixture, wherein

the premixed-gas-mixture-autoignition-start-time estimation means

estimates the time at which the premixed gas mixture starts autoignition, on the basis of at least the acquired cylinder interior gas state quantity at the time of start of compression, the estimated compression-attributable interior gas state quantity change amount, and the estimated cool-flame-heat-generation-quantity-corresponding value.

2. A gas-mixture-ignition-time estimation apparatus for an internal combustion engine according to claim 1, wherein

the cool-flame-heat-generation-quantity estimation means is configured to estimate the cool-flame-heat-generation-quantity-corresponding value on the basis of at least the injection quantity of the fuel for premixed-charge compression ignition combustion, the nature of the fuel, the oxygen concentration of an intake gas taken into the combustion chamber, and the density of the cylinder interior gas.

3. A gas-mixture-ignition-time estimation apparatus for an internal combustion engine according to claim 1, wherein the premixed-gas-mixture-autoignition-start-time estimation means comprises premixed-gas-mixture-temperature estimation means for estimating the temperature of the premixed gas mixture on the basis of at least the acquired cylinder interior gas state quantity at the time of start of compression, the estimated compression-attributable interior gas state quantity change amount, and the estimated cool-flame-heat-generation-quantity-corresponding value, and estimates, as the premixed-gas-mixture autoignition start time, a time when the estimated

temperature of the premixed gas mixture reaches a predetermined temperature.

4. A gas-mixture-ignition-time estimation apparatus for an internal combustion engine according to claim 1, further comprising adhesion quantity estimation means for estimating a quantity of fuel adhering to an inner wall surface of the combustion chamber at the time of start of the cool flame, the fuel being a portion of the fuel injected into the combustion chamber for premixed-charge compression ignition combustion, wherein the cool-flame-heat-generation-quantity estimation means is configured to estimate the cool-flame-heat-generation-quantity-corresponding value in consideration of the estimated adhesion quantity.

5. A gas-mixture-ignition-time estimation apparatus for an internal combustion engine according to claim 1, further comprising dispersion degree estimation means for estimating a value which represents the degree to which the premixed gas mixture disperses to the vicinity of the inner wall surface of the combustion chamber at the time of start of the cool flame, on the basis of a time elapsed between start of injection of the fuel for premixed-charge compression ignition combustion into the combustion chamber and start of the cool flame, wherein the cool-flame-heat-generation-quantity estimation means is configured to estimate the cool-flame-heat-generation-quantity-corresponding value in consideration of the estimated value representing the degree of dispersion.

6. A gas-mixture-ignition-time estimation apparatus for an internal

combustion engine according to claim 3, further comprising nonuniformity degree estimation means for estimating a value representing the degree of nonuniformity of the premixed gas mixture at the time of start of the cool flame, wherein the premixed-gas-mixture-temperature estimation means is configured to estimate the temperature of the premixed gas mixture in consideration of the value representing the nonuniformity degree of the premixed gas mixture.

7. A gas-mixture-ignition-time estimation apparatus for an internal combustion engine according to claim 1, wherein the premixed-gas-mixture-autoignition-start-time estimation means is configured to complete estimation of the premixed-gas-mixture autoignition start time at a predetermined point in time after start of compression of the cylinder interior gas and before start of injection of the fuel for premixed-charge compression ignition combustion.

8. A control apparatus for an internal combustion engine, comprising:

data storage means for storing data which define the relation between an operation state quantity of the internal combustion engine and a range of the autoignition start time of the premixed gas mixture for bringing the internal combustion engine into a state suitable for premixed-charge compression ignition combustion;

operation state quantity acquisition means for acquiring the operation state quantity of the internal combustion engine;

determination means for determining whether the premixed-gas-mixture autoignition start time in the present operation cycle

estimated by means of the gas-mixture-ignition-time estimation apparatus for an internal combustion engine according to claim 7 falls within the range of the autoignition start time of the premixed gas mixture obtained on the basis of the acquired operation state quantity of the engine and the data; and

fuel injection mode control means for controlling a fuel injection mode in the present operation cycle on the basis of the results of determination by the determination means.

9. A control apparatus for an internal combustion engine according to claim 8, further comprising data correction means for correcting the data in accordance with at least one of the oxygen concentration of an intake gas taken into a combustion chamber and the quantity of a gas within the combustion chamber.

10. A control apparatus for an internal combustion engine according to claim 8, wherein

when the estimated premixed-gas-mixture autoignition start time in the present operation cycle falls within the obtained range of the autoignition start time of the premixed gas mixture, the fuel injection mode control means injects into the combustion chamber the entire fuel of a demanded fuel injection quantity determined in accordance with the operation state quantity as fuel for premixed-charge compression ignition combustion earlier than a near compression top dead center;

when the estimated premixed-gas-mixture autoignition start time in the present operation cycle deviates from the obtained range of the

autoignition start time of the premixed gas mixture in a delaying direction, the fuel injection mode control means injects into the combustion chamber the entire fuel of the demanded fuel injection quantity as fuel for diffusion combustion at the near compression top dead center; and

when the estimated premixed-gas-mixture autoignition start time in the present operation cycle deviates from the obtained range of the autoignition start time of the premixed gas mixture in an advancing direction, the fuel injection mode control means injects into the combustion chamber a predetermined quantity of fuel, which is a portion of the fuel of the demanded fuel injection quantity, as the fuel for premixed-charge compression ignition combustion earlier than the near compression top dead center, and injects the remaining portion of the fuel of the demanded fuel injection quantity as the fuel for diffusion combustion at the near compression top dead center.

11. A control apparatus for an internal combustion engine according to claim 10, wherein when the estimated premixed-gas-mixture autoignition start time in the present operation cycle deviates from the obtained range of the autoignition start time of the premixed gas mixture in an advancing direction, the fuel injection mode control means sets the predetermined quantity of the fuel injected as the fuel for premixed-charge compression ignition combustion to a fuel injection quantity for premixed-charge compression ignition combustion which is necessary to bring the estimated premixed-gas-mixture autoignition start time in the present operation cycle to the obtained range of the autoignition start time of the premixed gas mixture.

12. A control apparatus for an internal combustion engine according to claim 8, further comprising nonuniformity degree estimation means for estimating a value representing the degree of nonuniformity of the premixed gas mixture at the time of start of the cool flame, wherein the determination means performs the determination in consideration of the value representing the nonuniformity degree of the premixed gas mixture.

13. A control apparatus for an internal combustion engine according to claim 8, wherein

when the estimated premixed-gas-mixture autoignition start time in the present operation cycle falls within the obtained range of the autoignition start time of the premixed gas mixture, the fuel injection mode control means injects into the combustion chamber the entirety of fuel of the demanded fuel injection quantity determined in accordance with the operation state quantity as fuel for premixed-charge compression ignition combustion from a predetermined injection start time which is determined in accordance with the operation state quantity and is earlier than a near compression top dead center; and

when the estimated premixed-gas-mixture autoignition start time in the present operation cycle falls outside the obtained range of the autoignition start time of the premixed gas mixture, the fuel injection mode control means corrects the predetermined injection start time in order to bring the actual premixed-gas-mixture autoignition start time in the present operation cycle into the obtained range of the autoignition start time of the premixed gas mixture, and injects into the combustion chamber the entirety

of fuel of the demanded fuel injection quantity determined in accordance with the operation state quantity as the fuel for premixed-charge compression ignition combustion from the corrected injection start time.

14. A control apparatus for an internal combustion engine according to claim 8, wherein

when the estimated premixed-gas-mixture autoignition start time in the present operation cycle falls within the obtained range of the autoignition start time of the premixed gas mixture, the fuel injection mode control means injects into the combustion chamber the entirety of fuel of the demanded fuel injection quantity determined in accordance with the operation state quantity as fuel for premixed-charge compression ignition combustion earlier than a near compression top dead center and under a predetermined injection pressure determined in accordance with the operation state quantity; and

when the estimated premixed-gas-mixture autoignition start time in the present operation cycle falls outside the obtained range of the autoignition start time of the premixed gas mixture, the fuel injection mode control means corrects the predetermined injection pressure in order to bring the actual premixed-gas-mixture autoignition start time in the present operation cycle into the obtained range of the autoignition start time of the premixed gas mixture, and injects into the combustion chamber the entirety of fuel of the demanded fuel injection quantity determined in accordance with the operation state quantity as the fuel for premixed-charge compression ignition combustion earlier than the near compression top dead center and under the corrected predetermined injection pressure.

15. A control apparatus for an internal combustion engine according to claim 8, comprising, in place of the fuel injection mode control means, premixed-gas-mixture temperature adjustment means, wherein

when the estimated premixed-gas-mixture autoignition start time in the present operation cycle falls outside the obtained range of the autoignition start time of the premixed gas mixture, the premixed-gas-mixture temperature adjustment means increases or decreases the temperature of the premixed gas mixture in the present operation cycle by a predetermined amount in order to bring the actual premixed-gas-mixture autoignition start time in the present operation cycle into the obtained range of the autoignition start time of the premixed gas mixture.